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GEOLOGY OF THE NORTHWEST TERRITORIES

A SUMMARY

HISTORY

The framework of the geology of the NWT was sketched by early naturalists, explorers and around the turn of the century by Geological Survey of Canada Officers who made legendary treks by boat and on foot across the taiga, mountains and barrens. R.G. McConnell, J.B. Tyrell, J.M. Bell, Joe Keele, Charles Camsell, A.P. Low and G.A. Young all made trips where the dangers from hostile natives, starvation, and the risks inherant in travelling in rugged terrain and on turbulent rivers without topographic maps, were always present.

Modern technological advancements, the most important of which were the airplane, photography and the outboard motor permitted rapid strides to be made during the decades between the two World Wars setting the stage for new scientific techniques typified by the airborne magnetometer and isotopic dating, which combined with the helicopter, permitted a data explosion to begin in the geological sciences during the 1950's. Thus a firm grasp of the fundamentals of NWT geology has developed in the last two decades.

THE GEOLOGICAL FRAMEWORK - NORTH AMERICA

North America consists of a stable interior platform, whose foundation is the Canadian Shield, surrounded by younger mobile belts (Cordilleran to the west, Appalachian to the east and Innuitian to the north). Vast regions of the stable platform were depressed at various times to become the sites of extensive Phanerozoic (post Precambrian approx. 500 million years to present) sedimentation.

The Phanerozoic (Paleozoic, Mesozoic and Cenozoic) sedimentary rocks contain the major portion of the continents mineral wealth. This is related directly or indirectly to the abundance of life in the shallow inland seas in which these sediments accumulated. Petroleum, natural gas, oil sands, coal and oil shales are clear enough examples, and they alone would be sufficent to justify the above statement. But the deposition of the major deposits of lead-zinc and cadmium at Pine Point and in the Mississippi Valley of the USA, were also controlled by organically produced reductants, as are the uranium deposits in the southwestern USA.

On other continents and in older rocks major sources of copper and uranium are also controlled by organically produced reductants. In the world's major gold source, the Witswatersrand, there is such a close association of gold with organic matter, presumably algal-mat growths, that a depositional control is strongly suggested.

Gold accumulations in many NWT deposits - Lupin at Contwoyto Lake, Cullaton Lake, Discovery, Camlaren and possibly even the Con and Giant for example are also closely associated with reducing conditions probably dependant of organically produced reductants.

GEOLOGICAL FRAMEWORK - NWT

The geological and tectonic maps of Canada show the NWT (Fig-1) contains all or parts of most of the geological provinces which we are now able to recognize.

Only the Pacific Continental Shelf, Appalachian Orogen, and the Nain, Southern and Grenville Provinces of the Canadian Shield are missing.

Geological or structural Provinces are areas of large size which contain rocks that are of similar age and have undergone similar geological events. The interior platforms for instance contain rocks deposited in dominantly shallow epicontinental seas developed across the deeply eroded metamorphosed rocks of the Canadian Shield. The NWT contains a large piece of the Interior Platform, most of the Hudson Bay Platform, and all of the Arctic Platform.

The geology and mineral deposits of the NWT will be treated province by province, except for the recent and Pleistocene which transgressed all the 10 (or more) subprovinces that can be recognized.

PLEISTOCENE AND RECENT

The most recent geological events have had a most important effect on the physiography of the NWT. Mountainous areas were eroded by valley glaciers which oversteepened valley walls, produced deep fiords and developed a system of 'glint' lakes that stretches around the border of the Canadian Shield from Bluenose and Great Bear Lakes to Montreal.

Structural Province boundaries within the shield are also zones of deep erosion by ice. Examples are Bathurst Inlet and the incredibly deep bays of the East Arm of Great Slave Lake.

The effect of glaciation on soils (commonly removing them) and weathered rock, though less intense beneath the centers of ice sheets than at the edges, has made vast tracts of the NWT unsuited for agriculture and has removed or confused the geochemical guides to ore deposits that are used in more temperate climes.

Gravel, sand and clay deposits of economic value have been produced in abundance, though in some places, eg. Yellowknife, gravel is in short supply. Part of the extremely large glacial lake McConnell covered the Yellowknife area. Our gravel deposit near the airport is part of an outwash delta built into this lake. The airport and the main area of the city is built on sands deposited by the same stream. Glacial till is rare around Yellowknife. As the lake slowly subsided it washed the fines from the exposed till adding to the sand plains developing extensive silt deposits and leaving scattered boulders littering the bedrock to mark the sites of the till blanket. Till is now found only where it was preserved in valley bottoms, where it is commonly covered by lake silt and peat.

Permafrost is discontinuous but is a major problem in construction and maintenance of houses, roads and other municipal services.

Giant Mines operates its open pits mainly in winter when it is safe to expose the ice rich clays of the Baker Creek valley. In summer they are kept covered by a thick blanket of waste rock to prevent thawing.

ARCTIC COASTAL PLAIN

The Arctic Coastal Plain is the youngest geological province represented in NWT (Table 1). It formed along the margin of the continent (Innuitian and Cordilleran Provinces) in response to Mesozoic continental drift and Arctic Ocean 'sea-floor-spreading' which formed the Canada Basin (Jones 1980). Sediment from the bordering lands and from the ancestral Mackenzie River built the coastal plains and delta, and continue to extend these today.

Oil and gas are present, but other economic mineral deposits are unknown.

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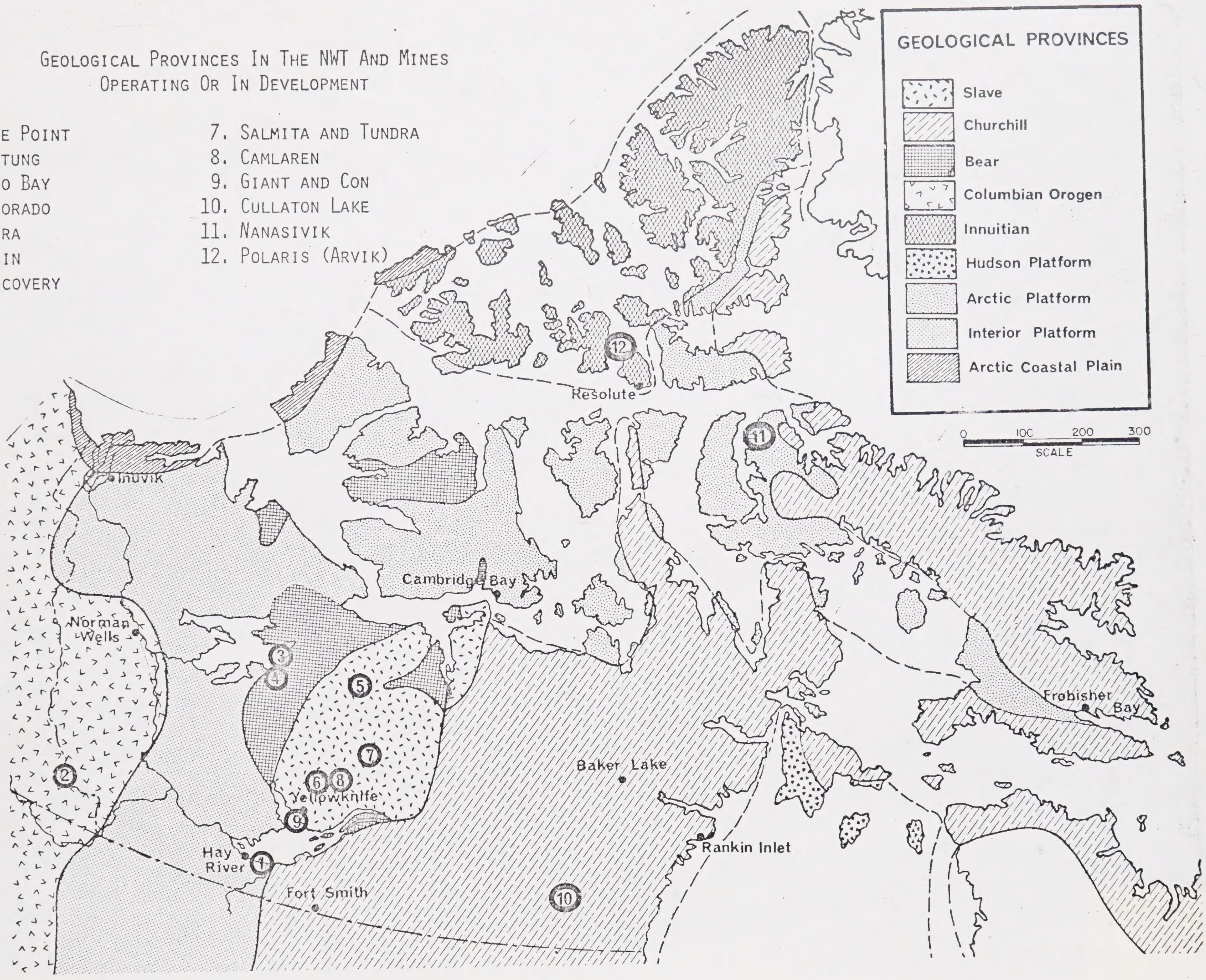
FIGURE 1 GEOLOGICAL PROVINCES IN THE NWT AND MINES OPERATING OR IN DEVELOPMENT

1. PINE POINT
2. CANTUNG
3. ECHO BAY
   ELDORADO
4. TERRA
5. LUPIN
6. DISCOVERY
7. SALMITA AND TUNDRA
8. CAMLAREN
9. GIANT AND CON
10. CULLATON LAKE
11. NANASIVIK
12. POLARIS (ARVIK)



INTERIOR PLATFORMS

Three relatively distinct areas of flat lying, (undeformed and unmetamorphosed) sedimentary rocks are recognized in the NWT. These are Hudson, Arctic and Interior platforms. The sediments on all these platforms were deposited in shallow inland seas mainly during the Paleozoic and Mesozoic Eras.

Hudson Platform, the smallest of these, contains the thinnest sequence of rocks which were deposited from Ordovician to Cretaceous (deposition has obviously recommenced with the Pleistocene-Recent sinking of Hudson Bay that was caused or triggered by glaciation).

There are oil shales on Southampton Island, (Nelson and Johnson 1976), but economic deposits have yet to be identified in these rocks.

Arctic Platform is a highly irregular area stretching from north of Great Bear Lake across the Islands and peninsulas of the High Arctic to Baffin and Ellesmere Island. It has persisted for a long period beginning in the Helikian (1.2 BY) when siliceous clastic rocks were deposited in what is now the northern end of Baffin and continued to collect locally sediment into the Mesozoic and Tertiary.

Relief is generally minimal except along the uplifted parts of Baffin and Ellesmere Island.

Two important areas of Mississippi Valley type lead-zinc mineralization are known. Nanasivik on northern Baffin Island and Polaris on the Arctic Platform - Innutian Orogen border zone on Little Cornwallis Island. Nanasivik Mine produces 1500 tons per day of ore grading 12% combined Pb & Zn from a two mile long ore body that has been deposited in a sinuous cave system. Cross bedding formed by reworking of sulphide sands, and stalactites formed by the deposition of Pyrites indicate the ore was deposited by a ground water system. Such deposits are epigenetic in that the main host-rock body was formed then prepared by solution of the cave (Karst formation) prior to deposition of the ore. Though the ore body is large (6 or 7 million tons) for this type of deposit, additional ore bodies are yet to be found making Nanasivik marginally economic. (In contrast Pine Point has 40 or more separate ore-bodies which are on average only 1/2 as large as Nanasivik).

The Polaris deposit is of similar genesis to Nanasivik, but at ± 25 million tons of 10% Pb & Zn it is at least 4 times as large. Nearby are the Eclipse and Truro Island deposits which are of more typical Mississippi Valley deposit-type size (1-3 million tons) suggesting there will be more deposits found in this area of the Central Arctic.

Polaris and its satellite deposits lie on a widespread unconformity that cuts the host Thumb Mountain Formation. Where the limestone of the Thumb Mtn. has been removed by leaching (Karst formation) it has been replaced by dolomite and the lead, zinc, and iron sulphides galena, sphalerite and marcasite.

The Arvik Mine will begin production from the Polaris deposit in 1982 at around 2200 tons/day. At a grade of 10% combined lead & zinc, this is 220 tons per day of metal, approximately 40% of the production at Pine Point.

Oil and gas resources have not been reported from the Arctic platform though tar sands are present on Banks Island.

The Interior Platform is similar to the Arctic Platform. It comprises flat lying shallow water, clastic and carbonate sediments which contain significant oil, gas and lead-zinc deposits. The section of Paleozoic rocks is neither as thick nor as extensive as those on the Prairies and the oil and gas resources are correspondingly less abundant.

The Pine Point lead-zinc district is a major part of the NWT industrial economy. It now produces 45% of NWT mineral wealth, though 5 years it produced closer to 80% of it. New mines (Nanasivik) and expansion (Cantung) and the rapid increases in the price of gold, silver and tungsten have significantly reduced Pine Points percentage of the total mineral wealth production.

This district also absorbs a large number of the exploration dollars spent in the NWT. Pine Point Mines spends over $2 million on the search for new ore bodies and other groups active in the area probably spend in total as much again.

Pine Point Mines employs nearly 600 people to mine and process around 4 million tons of ore per year. About 100 people work in the open pits. The property is 39 miles long and about 10 miles wide.

One of the biggest problems in pit production is the long haulage distances. Hauls of 10 miles, usual at Pine Point are uncommon in the industry. There are 40 to 50 miles of heavy duty haul roads and about the same amount of miscellaneous roads on the property.

The operation's other main concern and cost item is pit unwatering. The ore horizon dips gently from east to west and many of the small deposits on the property are below the natural water table. Between 60 and 70 million gallons of water were pumped away every day (in 1977) to keep the pits dry, using about 1/3 of the operation's total power consumption in the process.

Pine Point's lead-zinc deposits are Mississippi Valley type. The ore is found in an extensive middle Devonian barrier reef complex trending in a westerly direction and plunging gently west. The area is covered with about 40 ft. of glacial till. The host sediments occupy a stratigraphic interval of 400 to 500 ft. and are known as the Pine Point group.

Fine sandy textured dolomite forms the lower part of the barrier. Above lie the crystalline Presqui'lle dolomite and limestone. Orebodies are prismatic lenses of mineralized breccia or flat-lying sheets or discontinuous lenses and runs at various depths. They vary in size from a few hundred thousand to several million tons.

Ore minerals are sphalerite and galena with cadmium sulphide but no silver.

INNUITIAN STRUCTURAL PROVINCE

Except for a small slice at the northern most tip of Greenland all of the Innutian Province lies in the NWT, (Fig 1). Parts of the Province are rugged, the Highlands host ice caps and valley glaciers and the climate is cold and inhospitable.

Only within the last 20 years has the geology of this region been elaborated mainly through the work of R. Thorsteinsson, E.T. Tozer and more recently H.P. Trettin, T.O. Frisch, Wm. Kerr, R.L. Christie and R.G. Blackadar.

Rocks range from late Proterozoic to Cretaceous, are dominated by various sedimentary units but there are volcanics and Devonian quartz diorite intrusions along the northwestern coasts of Axel Heiberg and Ellesmere Island.

Very little of the Innutian Orogen or Structural Province has been prospected let alone explored for mineral deposits. Lead-zinc and copper are known in the Cornwallis northwestern Devon Island area at the boundary zone with the Arctic Platform. But only the Polaris and its associated deposits seem likely to be economic in the near future. Coal is widespread but practically unexplored.

It is likely that large areas including the volcanic belts and intrusions of Axel Heiberg and Ellesmere Island will be interdicted from mineral

TABLE 1 BRIEF DESCRIPTIONS OF VARIOUS CHARACTERISTICS OF GEOLOGICAL PROVINCES OF NWT

	SUB-PROVINCE	AGE OF ROCKS AND FINAL METAMORPHISM	DOMINANT ROCK TYPES	PHYSIOGRAPHIC FORMS	MINERAL DEPOSITS
SLAVE	None	Supracrustals deposited on older granitic crust	Remnants of supracrustal basins bordered by volcanics and filled by thin but areally extensive turbiditic sediments locally intruded by younger (2.5 B.Y.±) granitics and separated from one another by vast areas of granitic and migmatitic rocks.	Slave Upland stable craton planned of by 2.4± B.Y. of erosion minor relief except along margins	Volcanogenic massive sulphides (Ag-Cu-Zn-Pb and Cu-Zn Au deposits) Gold in iron formations and in epigenetic veins, shear zones and stockworks.
BEAR	1. Wopmay Orogen 2. Great Bear Plutonic-Volcanic complex 3. Brock & Minto inliers 4. East Arm Fold Belt 5. Goulbourn Basin (Bathurst Inlet) 6. Akaitcho Group 7. Hornby Basin Coppermine Basalts	(1-4) 2.1 to 1.8 By (4-6) younger rocks 1.8 to 1.5 laid down in basins (4-7) Terminal sedimentation and volcanism to at least 1.2 By	(1,2,3 & 4) supracrustals deposited on margins of the Slave Province Metamorphosed and intruded by 1.9 - 1.7 B.Y. granitic rocks. (4,5,6 & 7) include abundant relatively unmetamorphosed clastic sediments, volcanics and extensive stromatolitic carbonates, 1.7 to 1.2 By	Bear Upland is similar to Slave Upland but tends to be more rugged Eg: East Arm and Bathurst Inlet areas	Silver deposits (locally uranium rich) Camsell River/Great Bear silver district. High grade small tonnage copper deposits in Coppermine basalts. Rare-earth deposits in 'Bear Age' Alkaline intrusions along Bear-Slave Boundary. Uranium deposits in clastic sediments laid down across eroded Wopmay Orogen. Copper in intrusive breccia pipes. Copper-cobalt-nickel in volcanic necks and associated with laccoliths in the East Arm.
CHURCHILL	1. Kaminak-Rankin Volcanic Belt 2. Northwestern Churchill Prov. 3. Prince Albert Belt 4. Various fold belts (Foxe, Belcher, Cape Smith, Labrador) 5. Thelon-Dubawnt Basin, Nonacho Basin	(1,2 & 3) Archean rocks re-metamorphosed and intruded by Hudsonian age 1.8 - 1.7 By granitics (1-4) include 2.1 By and younger sypracrustals metamorphosed by the Hudsonian event 1.7 - 1.2 By	Archean continental crust remnants embedded in (1-4) volcanics and clastic sediments developed through denudation of Archean elements with contributions from Aphebian volcanoes all intruded by Hudsonian grantics (5) continental clastic sediments, siltstones, sandstones, conglomerates in shallow basins developed across the eroded craton formed by Hudsonian metamorphism and intrusion.	Much like Bear Plateau: flat, glaciated terrain locally rugged particularly along the spreading rift separating Baffin from Greenland.	Volcanogenic massive sulphides in Archean volcanic enclaves and in later volcanic belts. Extensive iron deposits in Aphebian fold belts on Mellville Pen., Baffin and Belcher Is. Gold in iron formation Cullaton Lake - early Aphebian. Nickel in mafic rocks, Ferguson Lake. Uranium in sandstones and in other clastic rocks in the younger sequences.
INNUITIAN	1. Franklinian Geosycline 2. Sverdrup Basin 3. Cenozoic Geosyncline	1. 1.2 By to ± present Early Proterozoic to Upper Devorian 2. Carboniferous Lower Tertiary 3. Upper Tertiary Quarternary	Various sediments and volcanics throughout (1) laid down of Canadian Shield 2 and 3 follow on 1. Thick sequences of fine clastics in basin grading into sands and carbonates in shallow waters (shelves) (3) Thin largely non marine sediments marginal to thick marine section off the (present) coast.	Depressed mountain ranges fractured by faults related to drift of Greenland and development of Arctic Ocean.	Practically unknown. Oil, gas and coal - Also sulphur in saltdomes

TABLE 1 (cont.) Brief descriptions of characteristics of geological provinces of NWT

	SUB-PROVINCE	AGE OF ROCKS AND FINAL METAMORPHISM	DOMINANT ROCK TYPES	PHYSIOGRAPHIC FORMS	MINERAL DEPOSITS
CORDILLERA	Columbian Orogen mainly Mackenzie platform in N.W.T.	Helikian (1.2 By) to cretaceous	On Mackenzie Platform dominantly clastic sediments 1.2 - .6 B.Y. followed by carbonates and fine clastics (shales) - Typical of shallow water some volcanics locally deep water shales and carbonates in Selwyn Basin. Cretaceous quartz Monzonite intrusions along Mackenzie-Selwyn junction.	Mackenzie Mountains Mountain valleys & Plateaus	Gas and oil in front ranges (border with Interior platform) Mississippi Valley type lead-zinc deposits in Mackenzie's also silver-lead-zinc-copper veins (Cadillac). Redbed copper deposits in Helikian clastics (Coates Lake) with extensive low grade iron formation in Redstone Formation farther north. Important tungsten & copper deposits in contact-metamorphosed limestones and cherts around quartz monzonite intrusions along Selwyn Basin margin. Fine-grained syngenetic lead-zinc deposits in Selwyn Basin (mainly in Yukon) eg: Howards Pass. Extensive coal resources.
INTERIOR PLATFORMS	1. Hudson Bay 2. Arctic 3. Interior	(1) Helikian ± 1.2 By to mesozoic (2) Ordovician to Cretaceous (3) Cambrian to Cretaceous	All shelf type (shallow water) sediments, limestones, shale, sandstone.	Flat lying Plains, gentle hills	Vast oil and gas reserves in 3 Potential in 1 considerable Lead-zinc in Hadrynian (Nanasivik) and Devonian, Pine Point and Arvik Extensive coal potential Oil Sands and Oil Shales present
ARCTIC COASTAL PLAIN	Mackenzie Delta Beaufort Sea Basin	Upper Cretaceous ± 65 my to present	Clastic sediments grading from shallow shelf type along coast to deep water type in basin	Coastal plain and subsea slopes, large delta	Oil and gas other resources not known

exploration before any idea of their potential is obtained. Geologically similar areas in the Cordillera produce vast amounts of copper, tungsten, molybdenum and gold.

CORDILLERAN STRUCTURAL PROVINCE

This Province borders the west coast of North and South America from Pantagonia to the Bering Sea. It is an extremely complex zone and can be divided into many sub-provinces, only two of which are represented in the N.W.T. The Columbian Orogen, the eastern portion of the Cordillera is represented in the NWT by the Mackenzie Arc, a zone in which shelf or platform sediments dominate and the eastern most portion of the Selwyn Basin where deep water shales and mudstones predominate. The border between the Selwyn Basin and the Mackenzie Platform is an important geological discontinuity that later became the locus of Cretaceous quartz monzonite intrusions many of which carry minor amounts of gold, copper, tungsten and traces of other economically important elements.

The Canada Tungsten Mine, at Tungsten just inside the NWT Border, produces high grade tungsten concentrates (sheelite) from an extensive deposit hosted by Cambrian limestones and cherts. It is probably the largest tungsten producer in the Americas and possibly in the world, since its throughput was increased from 600 to over 1000 tons per day by a recent expansion. Value of production now ranges from 50 to 80 million dollars a year, (depending of course on the normally volatile price of tungsten). This represents from 10 to 25% of the NWT mineral production.

There are a number of tungsten deposits along the border including the immense Mactung Deposit in the Yukon and the Lened deposit just north of Tungsten.

There are numerous shale hosted lead-zinc deposits in the Selwyn Basin, most are in the Yukon. Indeed the Selwyn Basin with perhaps 10 major lead-zinc deposits now identified, is one of the world's important lead-zinc districts, though it production is as yet smaller than Pine Point's. Shale hosted lead-zinc deposits are syngenetic, that is they were formed at the same time as the enclosing sediments. Where the orebodies are least deformed and metamorphosed (eg. Howards Pass) the mineralization is extremely fine grained which presents major metallurgical problems. Ore zones are developed in sub-basins where water circulation was restricted and where lead and zinc ions, probably reaching the sea floor through fault zones (as in the East Pacific rise), were deposited through reduction by decaying organic matter.

Such processes may explain numerous ore deposits, which indicates the importance of life processes as a geological agent. Carfull studies of Archean ore deposits have lead many investigators to suggest that the biomass present in the early geological eras was of a similar order of magnitude as is present today, for ore deposits formed in those periods are remarkably similar to phanerozoic deposits, and similar to those forming in the oceans at present.

The Mackenzie Mountains are built dominantly of siliceous clastic rocks - shale, siltstone, sandstone and abundant, thick sequences of carbonate. Mineral deposits are abundant and widespread, but as yet none are in production (ie there are mineral deposits, of economically valuable minerals, but no ore deposits).

The oldest mineral deposits in the Mackenzie Mountains are contained in Helikian/Hadrynian (Late Proterozoic) Mackenzie Mountain Supergroup clastic/carbonate rocks. This is the 'Redstone Copper belt' one of the worlds great accumulations of sedimentary type copper deposits.

These deposits contain cholcocite-bornite and cholcopyrite in relatively thin beds. Though not yet considered economic in the Mackenzie Mountains, similar deposits in Silesia (Poland) and on the Rhodesian Copper belt (Zambia) supply a large part of the worlds copper. Jefferson (1978) describes the deposits as follows:

> Copper mineralization developed under evaporitic, sabkha conditions in sediments that were deposited during a period of marine transgression. Disseminated copper deposits at Coates Lake are stratiform and repetitive in up to seven laterally continuous beds of cryptalgal-laminated limestone. Elsewhere in the copper belt, disseminated copper sulphides occur at the same general stratigraphic position, but there is generally only a single red bed to limestone transition, and the occurrences are highly variable in thickness and continuity. Throughout the copper belt, sedimentary features of both host sedimentary rocks and sulphides support a syngenetic to early diagenetic age of mineralization.
>
> Different styles of mineralization in different parts of the copper belt are apparently related to differences in tectonics and sedimentation. The Coates Lake embayment appears to have enjoyed tectonic hiati allowing access to quiet marine and sabkha conditions during several successive periods of transgression. Other embayments underwent transgression that was too rapid to allow significant development of algal laminites at shoreline conditions. They also appear to have had more irregular shoreline configurations causing rapid small-scale lateral facies changes, ponding and restriction of circulation of mineralization solutions, whether they were of marine reflux or formation origin. Secondary remobilization of copper related to growth faulting is also a possible consideration.

Lord (1978) has proposed the following: 'genetic model of copper deposition' "copper is leached from the underlying clastic rocks by circulating brine solutions and deposited when reducing conditions are encountered such as in decaying algal mats. The decaying algal mats of this model are possibly represented by the cryptalgal micritic carbonates of the Redstone River Formation."

In the Upper Proterozoic Rapitan Group, a dominantly glacial-marine and marine clastic section that reaches a thickness of 2,200 m, there are extensive hematitic iron deposits, probably the largest in North America. The best known and only adequately explored part of these iron deposits lie in the Snake River drainage basin of the Yukon.

Lead-zinc and copper is present in younger carbonate rocks of the Mackenzie Arc (Mtns). The more important deposits of Pb-Zn are Mississippi Valley type, but there are vein types as well.

None found to date are large enough to carry the immense infrastructure cost that would attend their mining.

Vein type silver-lead-zinc-copper deposits, Cadillac Mines, on Prairie Creek should be the next - (second) mining operation in the Nahanni District. These epigenetic deposits are narrow but extend for thousands of feet across the country side. A silver content of 5 to 50 ounces per ton causes the main interest in these deposits. Unfortunately the silver is firmly locked into the base metal sulphides, so a concentrate as opposed to silver bullion, or a native silver 'jig' product must be prepared. Such a concentrate is mainly base metal and sulphur which causes it to be heavy and bulky and require ground transport. The Great Bear Lake silver deposits on the other hand produce much of their silver as a high grade jig concentrate composed mainly of native silver which for its weight is so valuable that it can be flown out. In fact it is cheaper to do so considering current interest rates on silver tied up for a few months in transit.

The only pipeline into the north taps natural gas in the Pointed Mountain field (and adjacent Kootaneelee field in Yukon). The Norman Wells oil field lies on the border between the Mackenzie Arc and the Interior Platform. There may be additional oil and gas fields in the Mackenzies. There are coal fields in a number of places. Barite is widespread, but neither types of deposit have received much attention.

THE CANADIAN SHIELD

The Canadian Shield is the core zone of North America. It outcrops over roughly 1,864 million square miles and extends under the Interior Platforms northward to the Innuitian Province, westward to the Mackenzie and Rocky Mountains and southward to the Appalachian and Ouachita Mountains. The buried shield is thus at least equivalent in area to the exposed portion.

Four provinces of the Shield are present in the NWT, Proterozoic Churchill and Bear and Archean Slave and Superior.

Most of the Superior Province lies in Quebec, Ontario and Manitoba. That found in NWT form islands along the coast of Ungava and James Bay, off the shore of Quebec. In these areas there are no mineral deposits, though in the main areas of the Superior they occur in abundance.

CHURCHILL STRUCTURAL PROVINCE

The Churchill Province is probably the largest structural unit in the Canadian Shield. It extends from the middle of the east shore of Ellesmere Island 1,750 miles southeasterly to the Churchill River in Labrador and 1,750 miles southwesterly to just south of the Churchill River in Saskatchewan. It probably extends under the plains further to the south for 1,000 miles to north Texas and Oklahoma.

The geology of the Churchill Province is unrivalled in all the world for its complexity. With the exception of the Dubwant-Thelon and Athabasca basins, all the rocks of the Churchill Province have been metamorphosed and deformed to some degree and many of them have been exposed to such high temperatures that granitic melts have been produced to form migmatites and widespread granitic intrusions.

Part of the complexity of the Churchill Province stems from its formation by sedimentation from and vulcanism around rafts of older granitic crust which are now recognized as Archean enclaves. These have been found in the Wollaston Lake Belt of Saskatchewan, and are widespread in the Keewatin District.

The Rankin-Ennadai volcanic belt is one of the most extensive of the Archean Age-Subprovinces in the Churchill. It stretches for 300 miles southwesterly from Rankin Inlet and averages about 50 miles wide. It is a complex of volcanics and sediments now wrapped around Archean intrusions remetamorphosed and intruded by Hudsonian granitoids. Early Proterozoic deposits - mainly shelf sediments laid down across and peripheral to the Archean rocks are caught up in the Hudsonian deformation adding considerably to the complexity.

South and east of the Slave Province and south of Great Slave Lake there are vast areas of high grade gneisses and crushed granitic rocks (Queen Maude Block). These are some of the most hungry looking rocks on the shield; they contain no mineral deposits of any consequence and are probably reworked Archean granitics. Davidson (1972) describes the Churchill Province as follows:

> The available evidence suggests that a large proportion of the gneissic and granitoid rocks in the Churchill Province may be a tectonically reworked Archean crystalline basement. The question that immediately arises is where are the granitic plutons produced during Hudsonian Orogeny that apparently affected so large a part of the Canadian Shield? Pluton-like areas of massive or homogeneous granitic rocks have been outlined by reconnaissance mapping, but Douglas (1969) designated most of these, as well as the undifferentiated gneiss and migmatite terranes in which they lie, as "older than the radiometric age obtained mainly by potassium-argon methods", and stated that "these rocks probably form part of a crystalline basement that has been regionally metamorphosed, but it is not known whether they have been remobilized or remelted". There are only two areas in the Churchill Province where he has assigned an Aphebian age to groups of homogeneous granitoid bodies: on southern Baffin Island, and around Nueltin Lake west of Hudson Bay. Some of the granitoid bodies in and adjacent to the Foxe fold-belt may also belong to this category. In general, unless bodies of granitoid rock are known to be magmatic intrusions that cut the younger Aphebian supracrustal rocks, it is an assumption that they were produced by Hudsonian Orogeny. Accordingly, granitoid plutons that can be attributed directly to the Hudsonian Orogeny are volumetrically of minor importance in the Churchill Province, and much of the large volume of granitic rock in the Province may represent an older basement, at least in part of Archean age, that was more or less reworked during Hudsonian Orogeny. There is no evidence as yet to suggest that the Aphebian strata in the Churchill Province were not all deposited on a sialic crust.

In Archean and Proterozoic volcanic belts of the Churchill Province there are a number of volcanogenic sulphide deposits (Flin Flon and Snowlake are the largest and most important examples). There are a few in the Keewatin, but as yet none have reached production in the NWT.

There are also gold deposits of various type - Cullaton Lake is the first of these in NWT to reach production (August or Sept. 1981). But there have been ones producing in Saskatchewan and Manitoba. Cullaton Lake is a syngenetic deposit hosted by Aphebian iron formation (iron rich sediments). The gold is believed to have been deposited by sedimentary/volcanic processes in the sea contemporaneously with the iron rich minerals and the other components of the rock.

The Keewatin part of the Churchill also contains nickel deposits, one was mined at Rankin in the 50's. Another at Ferguson Lake is "on the shelf".

The most abundant and wide spread resource in the Churchill Province is the iron in its iron formation. Vast reserves are presently being tapped in the Ungava fold belt on the Quebec/Labrador border. There are large high-grade iron deposits at Mary River, Northern Baffin and immense low grade iron resources at Eqe Bay on the west coast of central Baffin and on Mellville peninsula as well as in the southern part of the Ungava belt in the Belcher Islands.

It is unlikely that any of these will be mineable in the near future.

BEAR STRUCTURAL PROVINCE

The Bear Province is almost the same age as the Churchill but because of its much smaller size and simpler history, it is geologically less complex.

The younger parts of the Bear Province are basins filled with post-tectonic sediments and volcanics - East Arm, Bathurst Inlet and Kilohigok Basin which contains the Goulburn Group of strata, Amundsen Basin with the Coppermine lavas, and the Hornby and Dismal Lakes groups.

The sediments in these basins are mainly continentally derived mudstones, immature siltstones sands, conglomerates and interbedded carbonates that are locally stromatolitic.

Mineral deposits in these rocks include uranium in the East Arm and Hornby Basin sandstones and siltstones and high grade chalcocite (Cu_2S) copper veins developed in fault zones cutting the Coppermine Lavas. Native copper is common in this area mainly as small blebs filling gas bubbles (vesticules) in the lavas but locally as sheets weighing many tens of pounds.

The largest of the copper deposit the C-47 zone contains about 3 million tons of material grading 5% Cu. Concentrate from such chalcocite deposits would contain 70% or so copper as compared to the 23 ± % Cu of concentrate from chalcopyrite deposits - such as the porphyry coppers of the Cordillera or the Volcanogenic massive sulphides of Flin Flon, Noranda, Kid Creek or Bathurst, N.B.

Beneath (underlying) the unmetamorphosed shelf sediments of the young basins are complexly deformed and metamorphosed rocks of the Slave Province of the Wopmay Orogen and of the Great Bear Volcano-Plutonic complex - parts of the Bear Province. Metamorphosed and highly deformed early Aphebian rocks are also present at the west end of the East Arm of Great Slave Lake.

The Wopmay Orogen is the most complex part of the Great Bear Province. Its geological history is currently being unravelled by P.F. Hoffman and his coworkers of the Geological Survey of Canada and various universities. This work has shown that the 'Wilson' cycle of ocean floor rifting, which powers orogeny to form continental crust and has been used so successfully to illustrate and codify Phanerozoic geological development can be extended back nearly another 2 BY to the lower Aphebian (2.5 BY).

No important or potentially mineable mineral deposits have been found in the Wopmay Orogenic belt and as it has been well mapped in the last 5 years, and because it is so well exposed, it is unlikely that the more obvious type of deposit such as the iron deposits of the Churchill or the gold and base metal deposits of Slave, or the silver-uranium deposits of the Great Bear district, exist in these rocks.

The Great Bear volcanic plutonic complex lies to the west of the Wopmay Orogen. It is a vast area of granitic rocks with thick and extensive accumulations of rhyolitic (acidic or siliceous) volcanic tuffs, agglomerates and breccias. Many of these were poured out as glowing avalanches of incandescent gas and glassy material similar to that which overwhelmed Pompei, St. Pierre on the Island of Martinique and more recently Spirit Lake at the foot of Mount St. Helens.

At a few places these rocks are cut by veins or disseminations of uranium, or by explosive-breccias (diatremes) mineralized with copper and uranium. One such deposit, the Sue-Dianne, is rumoured to contain in excess of a million tons grading 3% copper. It lies near the old Rayrock uranium mine some 25 miles north of Fort Rae.

The most important mineral deposits in the Bear Province, both historically and economically are the silver rich veins of the Camsell River and Echo Bay Silver District.

Silver-cobalt and Uranium-radium were discovered on Echo Bay by Gilbert Labine in 1930. Shortly thereafter the first mine began to work in the NWT producing silver and radium which broke the monopoly on that material held until that time by production from the Belgian Congo. Later uranium production replaced that of silver and radium and this was used to build the first atomic bombs.

Following a short period of inactivity Echo Bay Mines Ltd. began silver production from eastern extensions of the same vein systems mined in the Eldorado. When Echo Bay veins were pretty well exhausted the company acquired the Eldorado Mine and silver ore is again being mined from the Territories' first mine.

Production is from narrow but locally extremely high grade quartz-carbonate hematite veins carrying abundant native silver, argentite (Ag_2S) with chalcopyrite galena and sphalerite. The veins are mainly in an andesite tuff and tend to die out in adjacent rock types.

In 1971 similar deposits began to be mined by Terra Mining on the Camsell River, 80 miles south of Echo Bay. Most of Terra's veins are in thin bedded, calcareous sediments and tuffaceous sediments and, as at Echo Bay, are in a portion of a vast andesitic volcano. The Echo Bay and Camsell districts are actually in the same volcanic edifice, the two parts of which have been separated 50 miles on a right lateral strike slip fault. At both localities recent detailed mapping indicate the mineralized veins lie along or near the margins of calderas, whose formative faults have been the conducts and deposition sites for the mineralizing solutions.

In addition to the silver deposits there are farther south a number of small, locally high grade pitchblende bearing veins and pods. None appear to be of any commercial value although there is possibilities of silver mineralization in such areas as well.

In the East Arm of Great Slave Lake there are a number of volcanic centers (plugs) mineralized sparsely with copper and cobalt, none appear to carry ore grades. Small high grade nickel-cobalt deposits associated with sill like intrusions have been mined on a small scale in the recent past but the complex metallurgy of such materials and the small size of the deposits made them uneconomic.

A gold-tungsten-copper-tin deposit in metamorphosed quartzose sandstones that form the Outpost Islands was mined in the forties and fifties but the mineralized zones are reportedly narrow. That and the logistics of exploration and development on these small islands made the mine uneconomic.

Barite veins of considerable size are present in the East Arm, a favourable location for cheap water transportation to the Mackenzie Delta where a market exists, but, the veins are in part in a 'Park reserve' and the barite may be high in heavy metals which may prohibit its use where disposal is into the sea or other fish habitat.

An important deposit of rare earths, mainly columbium (tantalum) with values in copper, uranium and fluorine occurs in the Blachford Lake complex, an alkaline intrusion of Bear Province age that cuts Slave Province rocks just north of Hearne Channel. This appears to be a large, perhaps huge deposit with a relatively favourable location for water transport. Whether such a deposit can compete with columbium produced cheaply from deeply weathered and easily mined deposits in Brazil is yet to be determined. The metallurgy of the deposits is also very complex.

SLAVE STRUCTURAL PROVINCE

Slave Structural Province is an Archean craton covering 75,000 sq. miles (190,000 km^2), Fig. 2. It is elliptical in shape measuring 250 by 400 miles and has two small outliers. One of these, the Bathurst block, the most northeasterly portion of the province has been moved 125 miles to the north on the left lateral Bathurst Fault zone. The Tree River outlier a much smaller block is separated from the main part of the Province by Proterozoic Akaitcho Group (Bear) sediments that fill a broad syncline along the Bear-Slave Boundary.

As with most Structural Provinces, the Slave resembles its contemporary, in this case Archean, crustal blocks, but there are many unusual or unique phenomenon displayed as well.

The Slave comprises basins filled with sediments and volcanics locally bordered by older granitoid gneisses and intrusions that have all been intruded, deformed and metamorphosed during the terminal Archean orogeny - called the Kenoran which ended about 2.5 BY. There are later intrusions including widespread diabase dykes (gabbros) and Aphebian (Bear) alkaline intrusives and in places a cover of late Proterozoic continentally derived clastics and carbonates - Mainly parts of the Kilohigok Basin.

The boundary of Slave on the west, north and south is an unconformity covered by Proterozoic Bear Province sediments. On the west this boundary zone is deformed and contorted (reworked) by the Wopmay Orogeny ± 1.75 By. The eastern boundary of the Slave, that with the Queen Maude Block of the Churchill Province, was thought to be a sharp demarcation, possibly a fault. This was called the Thelon Front. Work by Henderson and Thompson along this front in the last 3 years have shown it to be a myth. The transition from typical Slave Province supracrustal belts surrounded by Kenoran granitoids to the granitic gneisses is totally gradual and represents a transition from a high crustal level to a much deeper one. This change is shown by the gradual disappearance of the Slave Supracrustal belts and the appearance of more high temperature, high grade mineral assemblages. Thus the Queen Maude Block is not just a dominantly Proterozoic terrain like the Bear Province to the west of the Slave but a deeper level of the Archean (Slave) Craton which was uplifted gradually during the Aphebian (lower-Proterozoic) so that all K-Ar dates were reset to that later date and many Rb-Sr dates were disturbed. More resistant Isotopic systems (particularly the Pb-Ur of zircons) should show that this belt is in fact a continuation of the Slave Province locally reworked by Hudsonian (=Wopmay) Orogenic events.

A decade or so of detailed and reconnaisance geological mapping by government and mineral exploration company geologists has developed a new understanding of the Slave Province. This work has also shown the Slave shares many characteristics with half a dozen Archean cratons in other parts of the world, and like the Superior Province, contains numerous gold and volcanogenic base metal deposits.

There are approximately 20 discrete supracrustal belts in the Slave Province, Fig. 2. These are filled with sediment-volcanic complexes termed the Yellowknife Supergroup. This supergroup includes, at least where well preserved, a broad central expanse of turbiditic sediments, alternating greywacke sandstone and shale, that is locally intruded by elliptical Kenoran granitic plutons and is generally metamorphosed to greenschist or lower or middle amphibolite grade of metamorphism. The sediments have also been subjected to many phases of deformation resulting in complex structural patterns that because of the monotonous similarity of the greywackes are difficult to delineate except where exposure is excellent.

Around the borders of the greywacke - shale turbidite filled basins are belts of volcanic rocks such as that at Yellowknife. Volcanism appears to have been controlled and initiated by basin-bounding faults which tapped molten or melting material at depth. The volcanics of the province tend to be predominantly intermediate to siliceous in composition. Strongly mafic basalts are uncommon and ultramafic lavas that are well developed in many other Archean Volcanic belts have so far been found in only one of the Slaves many volcanic belts.

In many Slave Volcanic belts the initial volcanism is felsic suggesting that the Slave supracrustals were deposited on a pre-existant siliceous granitic terrain. The sparcity of mafic and ultra mafic lavas and the abundance of felsic (dacitic and rhyolitic) Volcanics supports this contention, as does the siliceous nature of many of the earliest sandstones and conglomerates associated with the volcanic belts.

Further evidence for this siliceous early crust is the granitic gneisses and migmatized rocks which underly or are marginal to the Slave supracrustals. Dates from these rocks range from 3.1 BY for pre-Yellowknife Supergroup granitoids to 2.7 BY for granitic gneisses developed prior to and intruded into the margins of the supracrustal basins.

COMPARISON OF SLAVE PROVINCE TO OTHER ARCHEAN CRATONS

Slave	Other
Supracrustal component is 80 - 90% sedimentary.	Volcanics form a large to overwhelming % of supracrustals.
Volcanic belts marginal to basins and begin with felsic outpourings	Volcanics main part of basin fill. Eruption along fractures not necessarily confined to basin margins.
Dominant volcanic rocks vary from andesitic-basalt (Yellowknife) to felsic rocks (dacite, rhyolite) (High Lake, Hackett)	Dominant rocks basaltic.
Terminal volcanics commonly most mafic types. At least basalts similar to main part of belt reappear in final volcanic phases.	Terminal volcanism reportedly more felsic. First formed flows commonly most mafic (in places ultramafic).
Supracrustal basins amoeboid in shape.	Supracrustals in elongate belts.
Most volcanogenic base metal deposits contain little gold but significant lead and silver.	Most volcanogenic base metal deposits contain little lead and silver but significant gold.

SLAVE MINERAL DEPOSITS

There are broadly speaking only two groups of mineral deposits in the Slave Province. These are gold deposits and Volcanogenic massive sulphide deposits. There are, however, a wide variety of genetic types of gold deposit, and considerable variety in the sulphide deposits.

Gold Deposits

Gold was discovered around the North Arm of Great Slave Lake many years before the first small production from the Burwash property across the bay from Yellowknife in 1935. A few years later the Con Mine reached production (1938) and Yellowknife became the centre of mineral production and development in the NWT.

The Yellowknife deposits are epigentic, the gold having been mobilized by metamorphic processes from deeply buried portions of the Yellowknife supracrustal rocks, carried with silica and calcium in CO_2 rich solutions to be deposited in shear and fracture zones during the complex deformation - metamorphic evolution of the belt. The host rocks for all the important deposits at Yellowknife are Kam Formation andesitic basalts which may be pillowed, massive or brecciated flow rocks. The shear zones comprise schistose quartz, carbonate sericite and chlorite rich schistose rock enclosing remnants of more or less unaltered, and usually barren Kam basalt. Such zones reach impressive widths in the Giant Shear System where grades of 1/2 ounce carried across widths of over 30 m. Locally thin quartz veins carrying high grade visible gold were also present notably in the RyCon and Negus 'shear' and at the Brock prospect.(Giants westerly most ore zone).

VOLCANIC BELTS IN THE SLAVE PROVINCE

NUMBERED ON FIGURE 2

1. Yellowknife Volcanic Belt; Giant, Con, Negus and Rycon Mines.

2. Thistlethwait Lake Volcanic Belt; Discovery Mine

3. Cameron River Volcanic Belt; Camlaren Mine

4. Turnback Lake Volcanic Belt; silver-lead deposits

5. Beaulieu Volcanic Belt

6. Indian Mountain Lake Volcanic Belt; zinc-lead, silver and copper deposits.

7. Camsell Lake Volcanic Belt

8. McKay Lake Volcanic Belt; Tundra and Salmita Mines, also zinc deposits.

9. Indin Lake Volcanic Belts; Colmac (Hydra) gold deposit and numerous small high grade gold-quartz veins.

10. Point Lake Volcanic Belt

11. Itchen Lake Volcanic Belt; Izok Lake, zinc-silver-lead-copper deposit

12. Redrock Lake Volcanic Belt

13. Contwoyto Lake Volcanic Belt

14. Takijuq Lake Volcanic Belt; zinc-copper-silver deposits

15. High Lake Volcanic Belt; High Lake copper-gold deposit

15A. Southern extension High Lake Belt

16. Anialik River Volcanic Belt; Acadia gold quartz veins in granitic rock within belt

17. Hope Bay Volcanic Belt; native silver and gold deposits

18. Hackett River Volcanic Belt; Bathurst Norsemines silver-zinc-copper-lead deposits, Yava and Musk in southern part of belt

19. Back River Volcanic Complex

20. Muskox Lake Volcanic Belt; gold deposits

21. Clinton-Colden Lake Volcanic Belt; zinc showings

22. Walmsley Lake Volcanic Belt

Legend for Figure 2 on facing page.

LEGEND

▨ Proterozoic cover rocks

▭ Proterozoic metamorphics and intrusives (Bear to west Churchill to east)

⊞ Kenoran Age intrusives

▧ Migmatite

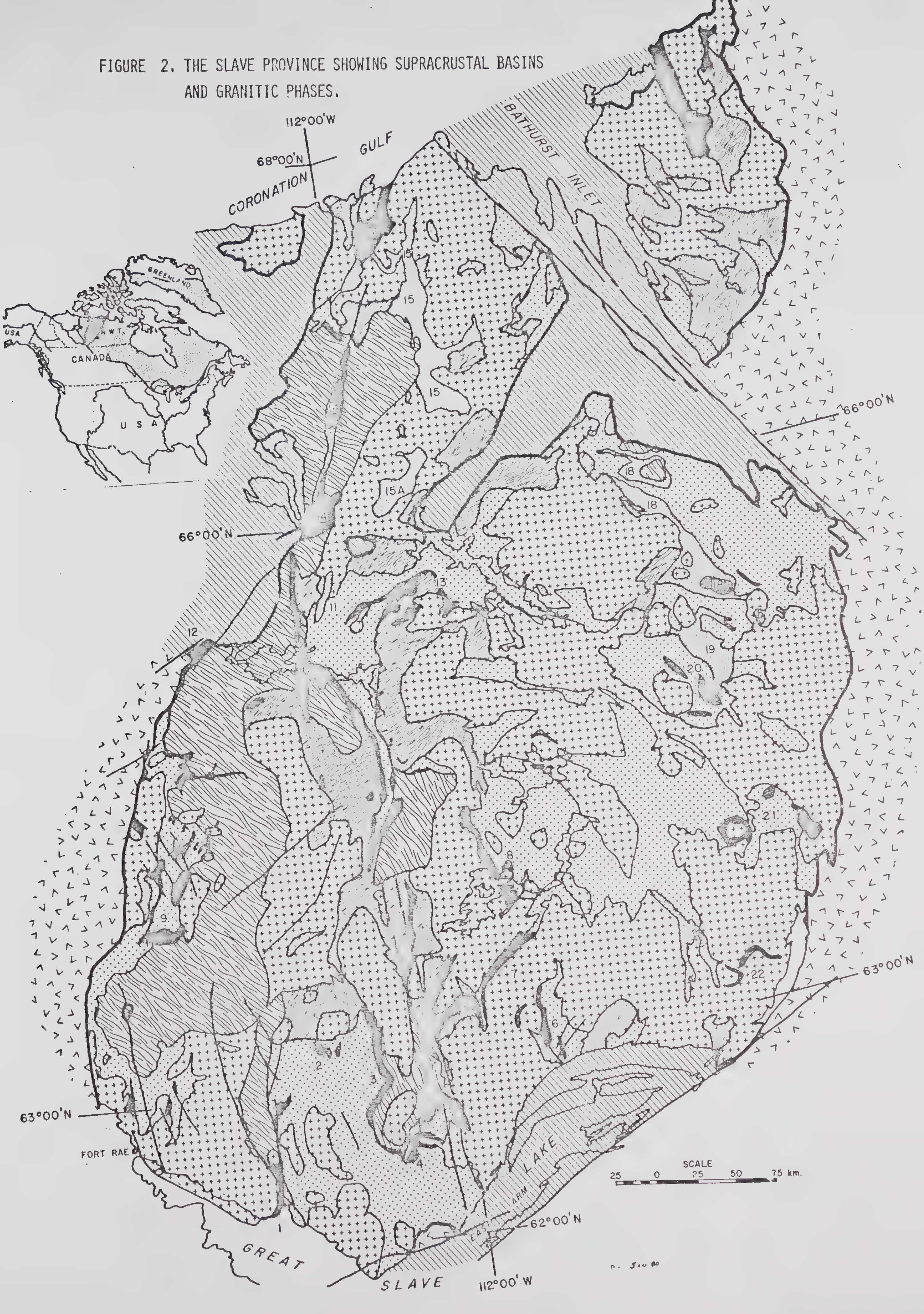
▒ Dominantly felsic volcanic belts

░ Metasediments, mainly turbidites

▰ Dominantly basaltic volcanics

▩ Metamorphics and intrusives including pre-Yellowknife Supergroup granitoid basement

FIGURE 2. THE SLAVE PROVINCE SHOWING SUPRACRUSTAL BASINS AND GRANITIC PHASES.



Ore from some parts of the Yellowknife deposits is 'free milling': Campbell RyCon and Negus zones; but that from the Con shear (now mined out) and the Giant Shear Zones have gold so closely associated with arsenopyrite that they must be roasted to remove the Arsenic and Sulphur which reacts with and destroys the cyanide solution and coats these gold particles within arsenopyrite crystals so that they cannot be dissolved.

Recently Giant solved, at least temporarily, their 'arsenic' problem by selling the arsenic to an American company, presumably to use as a timber preservative.

Throughout the greywacke - turbidite basins of the Slave Province particularly east of Yellowknife there are numerous small auriferous quartz veins that resemble the famous 'Saddle reef' deposits of Ballarat and Bendigo in Victoria (Australia). The Camlaren mine is probably the only saddle reef in the world now in production. Saddle reefs are quartz veins in folded sediments (usually in turbidites). The folding produced low pressure zones between the beds into which quartz and gold was mobilized. At Camlaren the zone containing the quartz vein is rich in graphite and the wall rocks are sulphide rich. Here also there is strong circumstantial evidence for organic material being an important element in the ore deposit generation.

In other parts of the Slave Province, Discovery and Tundra being examples, gold was mined from quartz rich zones associated with sulphide rich beds near the top of volcanic sequences. These areas are now being explored again to determine whether or not the sulphide rich zones can be economically developed.

Similar yet distinctly different deposits are widespread in the Contwoyto-Point Lake supracrustal basin where Echo Bay Mines is developing the Lupin deposit on Contwoyto Lake. This mine should be in production in 1982 at 1200 tons per day of circa 0.3 oz/ton. The output of 3 to 400 ounces per day is more than 50% of the current NWT output, and with Cullaton Lake and Salmitas production expected in the same period, the NWT's gold production will have doubled during the 1980's.

The Salmita deposit, near the old Tundra Mine is being developed by Giant Mines. It is similar to the Discovery deposit; quartz veins and stringers near the top of a volcanic pile and closely associated with sulphide rich volcanogenic sediments. Gold in the quartz rich zones may have been remobilized out of low grade portions of the supracrustal pile during metamorphism, but gold also commonly occurs in the sulphide rich beds, and this gold may be in part syngenetic and in part deposited within the rock by volcanic emanations.

The Contwoyto Lake type deposit and the somewhat similar Cullaton Lake deposit (in the Keewatin-Churchill Structural Province) are associations of gold with sedimentary accumulations of sulphide iron formation. At Lupin the mineralized beds are termed 'amphibolitic sulphide iron formation'. The rock is a fine grained matrix enclosing coarse crystals of arsenopyrite and the related iron rich arsenide loellingite. The gold is closely associated with these minerals. Echo Bay hopes to recover the gold by a low temperature cyanide leach which they contend will eliminate the problems Giant Yellowknife had in their early days when recovery hovered around 50%.

Contwoyto type deposits form syngenetically, (much like Howards Pass type lead-zinc deposits). When metal rich solutions are fed into small sub-basins within the larger turbidite (shale) basin, the small basins are isolated from the coarser sediment so that only a thin rain of the finest mud reaches them. Organisms feeding on the metal rich solutions die and decay in abundance. Sulphate is reduced to react with the metals which are deposited as iron and arsenical sulphides (and sphalerite and galena in base metal deposits). Gold carried in the solutions in ionic complexes is freed and is deposited in the arsenides as the native element. Later metamorphism causes some of the minerals to grow to large size and the gold coalesces into much larger aggregates. There may also be some concentration of gold, liberated by metamorphic processes, into the sulphide rich iron formation.

Cullaton Lake is different in that its host Aphebian iron formation was formed in a more stable shelf-type environment and the ore is low in arsenic.

There are a number of other gold deposit types in the Slave Province. The Arcadia deposit for instance comprises numerous quartz and quartz-iron sulphide veins developed in sheared fractures cutting the Anialik River granitic gneiss, on Grays Bay (Coronation Gulf). This gneiss intrudes the Yellowknife Supergroup, but its internal structure and its zincon (Pb-Ur) age 2.699 ± 5 BY indicate it is in fact older than the Yellowknife Supergroup volcanism and sedimentation (at around 2.6 BY). The Arcadia vein systems are the most extensive yet found outside the Yellowknife gold belt, and may be mined in the forseeable future.

Volcanogenic Massive Sulphides

Massive sulphide deposits in volcanic rocks usually formed as the volcanic pile accumulated and hence are commonly syngenetic. In many examples there are clasts (fragments) of sulphide in the sulphide beds indicating deposition at a previous time (or level) followed by explosive volcanism to blow the sulphide bed to pieces, followed by deposition in a new bed to form the ore deposit.

As yet there are no mines working massive sulphides in the NWT though deposits have been found in the Indian Mountain, Hackett River-Beachey Lake, High Lake and Itchen Lake-Takijuq volcanic belts (6, 18, 15 & 11-14, Fig. 2). The main problem now is the great distance from markets and the resultant high cost of transportation, which would leave very little income to pay for infrastructure (which is now almost totally absent economic rent and return on investment.

Most of the deposits in the Slave are richer in lead and silver, and leaner in gold than those in other Archean volcanic belts. The Izok Lake deposit is the largest found as yet. It contains 12 million tons of material averaging 2 oz Ag, 2.8% Cu, 13% Zn, 1.5% Pb high grade for even, volcanogenic massive sulphides, but it is probably only 15% of the tonnage needed to justify production at this time. There are, as well 4 or 5 much smaller deposits within 25 miles of Izok Lake.

On the Hackett River, 150 miles east of Izok there are 4 or 5 smaller deposits of slightly lower base metal grade but considerably higher silver content (21.5 million tons grading 4.37 oz Ag/ton, 0.75% Pb, 4.98% Zn, 0.41% Cu, 0.013 oz/ton Au). Though individually smaller the total tonnage is approximately 25 million, twice that of Izok.

Two smaller deposits, Yava and the Musk, have been found in the same volcanic belt 25 and 50 miles to the southeast. The Musk contains a significant tonnage grading more than 11 oz/ton of Ag and might be economic if the silver could be removed from the base metal sulphides, thus avoiding the vast cost of hauling thousands of tons of concentrate.

In the Slave Province, as in most Precambrian terrains, volcanogenic massive sulphide deposits are closely associated with the felsic (acidic, or siliceous) phases of volcanism. Where felsic volcanics are uncommon, or a small portion of the volcanic pile, for example at Yellowknife, the volcanogenic sulphide deposits, though present are small, low grade and of no possible value. To the north and northeast the volcanic

Base metals associated with felsic volcanism

Sphalerite-chalcopyrite-pyrite near Itchen Lake

An important discovery of zinc-copper-lead-silver mineralization about 2 miles (3.2 km) northwest of Itchen Lake (approximately 65°39′N, 112°49′W) was made by Texasgulf Inc. in the summer of 1975 (P.L. Money, pers. com., 1975). The deposit does not outcrop but is beneath a small lake known to Texasgulf as 'Izok' Lake. Its presence was suggested by mineralized float and was discovered by drilling from the ice. Over 7 million tons of indicated ore within the central zone of the deposit extend over a strike length of 1400 feet (427 m) open to the east. Two other zones have been found but not delineated. The average grade is 14.8 per cent zinc, 3.15 per cent copper, 1.20 per cent lead and 1.85 ounces per ton silver. The host rocks are quartzofeldspathic gneisses probably of volcanic origin that have undergone polyphase deformation. A typical section of the central zone (provided by Texasgulf) is shown in Figure 51.

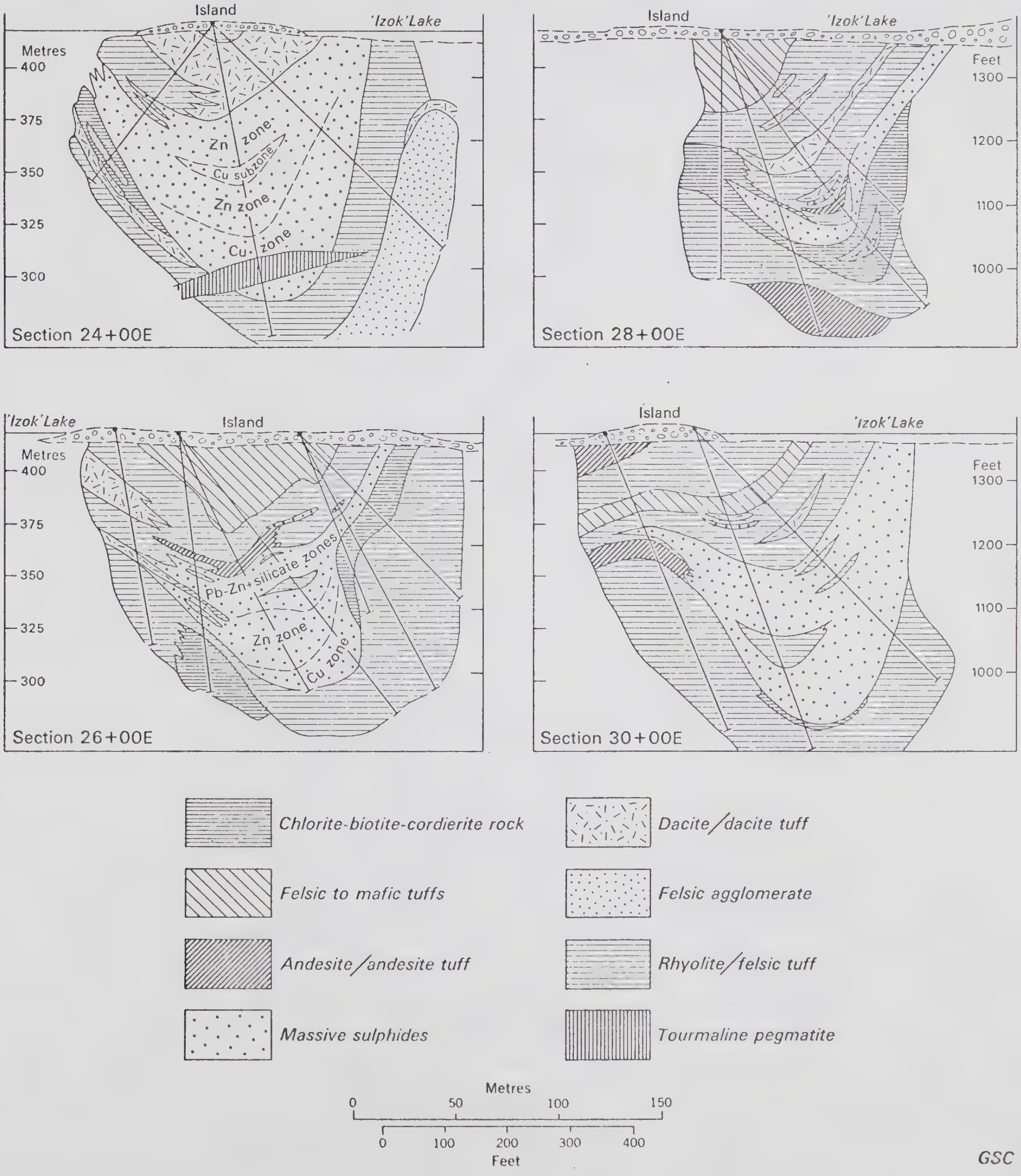


Figure 51. Representative section of the central zone, 'Izok' Lake base metal deposit (after Money and Heslop, 1976, Texasgulf Inc.).

piles are more felsic and sulphide deposits are much larger and richer.

Volcanogenic massive sulphides are deposited during the late phases of a volcanic cycle when pyroclastic and lava output has declined and has been largely replaced by fumarolic activity. Large volumes of water, mainly derived from the surface, (meteoric water), and driven through the rock by the volcanic heat. These waters dissolve heavy metals, silica and $CaCo_3$ and when they reach the surface at vent regions (fumaroles) they deposit their metals. A long period of volcanic quiescence is required to avoid diluting the metals too much with useless silicate material. Rocks beneath the sulphide deposit are altered by the leaching and the new minerals formed are useful indicators of mineralization.

A typical (but unusually high grade) massive sulphide, the Izok Lake deposit is shown in Figure -3, sketches from Bostocks 1981 Memoir on the Itchen Lake District.

Though gold is very important for the future economic development of the Slave Province, the volcanogenic base metal sulphide deposits should provide a much expanded base, because these deposits require a much higher level of infrastracture for their successful operation.

ECONOMIC MINERAL DEPOSITS OF THE N.W.T.

INTRODUCTION

The Northwest Territories is an immense region with few inhabitants. It has 1,253,438 square miles of land, (3,246,404 km^2) 51,405 square miles of fresh waters, 10,000 miles of sea coast and approximately one million square miles of inland sea and continental shelf which are frozen over for 6 to 12 months of the year. Its population (1979) of 45,880 is 34% Inuit, 18% Dene (Indian), 10% Metis and 38% other. In the Northwest Territories there is only one person for every 28 square miles of land.

Mining and mineral exploration, the dominant industrial activity, employ about 2,000 people full time in mining and as many more, mainly part time, in exploration. Government is the other major employer providing about 6,000 jobs. As a result about half of the people in the Territories with wage employment work for a government. Traditional pursuits, hunting, trapping, and fishing, are also of major importance, employing most of the native population.

The Inuit population is very young, the average age is approximately 15 years, and the birth rate is one of the highest in the world. Important mineral discoveries in Inuit lands (Map 1) include major polymetallic volcanogenic massive sulphide deposits (4,5,7) a large iron-formation hosted syngenetic gold deposit at Contwoyto Lake (east of 7) in the Slave Province, and numerous gold deposits of varying genesis grade and size in other parts of that province: an immense Mississippi Valley lead zinc deposit (2) in the High Arctic; one of the world's largest high grade iron deposits (1) on Baffin Island; and immense low grade iron deposits (3) on Melville Peninsula. Ultimately these deposits will be developed to help provide the employment that will be needed for this rapidly expanding Arctic population.

Important mineral discoveries have also been made in the 74,000 square miles of the Cordillera Province that lie in the N.W.T. (Map 1).

The value of mineral production from the six mines operated during 1978 (Map 2) is estimated at 295 million dollars, $5,276 for every N.W.T. inhabitant. Production in (1979) 1980 from nine mines is estimated at ($461) 543 million dollars, $1,184 per person. In much of the Territories, particularly the Barren lands, mineral exploration and mining are the only practical alternatives to employment in traditional hunting, trapping and fishing.

HISTORY OF MINING AND MINERAL EXPLORATION IN THE NORTHWEST TERRITORIES

The mineral potential of what is now the N.W.T. came briefly to the attention of Europeans through Martin Frobisher's ill fated and misconceived attempts to mine gold, which was pyrites, from islands in Frobisher Bay (1576 to 1578). Long before, Indians and Inuit had mined, or probably more correctly, collected native copper from the basalts of the Coppermine River area. Copper artifacts are common in wide-spread paleo-Indian camp sites east of Great Bear Lake. Rumours of rich copper deposits brought Samuel Hearne trekking northwesterly across the tundra from Churchill on Hudsons Bay to the mouth of the Coppermine on the Arctic Sea in 1771. Hearne wandered 5,000 miles, mainly on foot, setting a precedent for generations of prospectors who were to follow. More than 100 years later lead and zinc were found at Pine Point by gold seekers trying unsuccessfully to reach the Klondike via the Mackenzie River system. [According to Pine Point-Cominco geologists local natives (probably Slavis) showed the Klondike trekkers the galena rich outcrop.]

The mineral wealth of the Territories lay untapped for 450 years between Frobisher's departure for warmer climes and the discovery of rich silver-cobalt-radium-uranium deposits at Port Radium on the east shore of Great Bear Lake in 1930. Production was underway in 1934, a year prior to the discovery of gold at Yellowknife. In 1938 the first gold was produced from the Con Mine.

Mineral production expanded slowly as the various Yellowknife discoveries came on stream; Rycon and Negus (1939), Ptarmigan (1942), Giant Mine (1949), Lolor and Akaitcho (1967). Gold production began farther north at Discovery in 1950, Camlaren, 1962, and Tundra, 1964. Rankin Inlet Mine produced copper and nickel from 1957 to 1962; Canada Tungsten Mine began producing tungsten and copper in 1962, and has expanded production to circa 1000 tons per day to become the 'wests' if not the world's largest tungsten producer (at around $65 million worth of product in 1980). Echo Bay began silver-copper production in 1964 and Terra became a silver-copper producer in 1969. Minor production was won from the Rayrock (uranium) Mine (1957) and the Hope Bay (1974) and Norex (1970), silver mines.

When the lead-zinc deposits at Pine Point reached production in 1965 a new phase in mineral developments in the N.W.T. began. Value of yearly production increased almost ten fold and exploration expenditures increased by at least 800%.

Most of the major developments in the N.W.T. mineral industry began in the early 1960's and have continued to unfold to the present.

RECENT MINERAL EXPLORATION

Only one significant base metal find, the High Lake deposit (5 Map 1), was made in the 1960's.

During the mid 60's important mineral discoveries in the Coppermine River area (1966), around Pine Point (1965-66) and on the Wollaston trend in Saskatchewan (1968) resulted in extensive exploration for copper in the Coppermine River area (6 Map 1), for lead-zinc in the Pine Point area, and for uranium in the Keewatin District and in adjacent parts of the southeastern Mackenzie District. During the same period (1968) many hundreds of claims were staked in the Artillery Lake area, north of the eastern end of Great Slave Lake, following release of aeromagnetic maps that defined strong magnetic lineaments along the Slave-Churchill Province boundary. Hopes that a new nickel belt similar to that at Thompson, Manitoba had been found, were not borne out by the ensuing exploration.

With the exception of the Pine Point discoveries the exploration surge of the 1960's did not locate mineable deposits and by 1971-72 staking and exploration expenditures had fallen back to only slightly those at the beginning of the 60's.

As activity declined towards a ten year low,the ground work for new base metal discoveries by Cominco, Texasgulf and Canex Placer was quietly being laid in grassroots programs in the Slave Structural Province, in the Arctic Archipelago and in the Selwyn Basin of the Cordillera. These major discoveries, together with more recent exploration successes, promise to change the stature of mining in the N.W.T.

Between 1971 and 1975 Cominco Ltd. found a number of volganogenic base metal-silver deposits on their Bathurst Norsemines option on the Hackett River 450 km (300 miles) northeast of Yellowknife (4 Map 1). When exploration was curtailed here in 1975-76 slightly more than 20 million tons of copper-zinc-lead-silver 'ore' had been outlined in 4 deposits that are amenable to open pit mining. These discoveries and geochemical-geological reconnaissance that indicated an extensive belt of intermediate and felsic volcanics resulted in widespread staking for more than 60 miles (100 km) along almost the full length of the Hackett River volcanic belt. Two additional deposits of similar type, Ag basemetal (the Yava and Musk) deposits were found south of the Bathurst Norsemines Deposits.

In 1975, 160 km to the west, Texasgulf was drilling an even more impressive find in one of the Itchen Lake volcanic belts (7 Map 1). By 1976 Izok Lake deposit drilling had indicated 12 million tons of high grade copper-zinc-lead-silver 'ore', and two much smaller volcanogenic massive sulphide deposits had been located 40 km to the north in the Takijuq Lake area.

During 1974 to 1976 most of the volcanic belts in the northern half of the Slave Province were staked or taken under permit, and extensive ground exploration followed airborne magnetometer and EM surveys. Exploration expenditures reached new highs as a result, but major new finds have not been announced and by 1978 Slave Province base metal exploration had declined to less than 25% of the 1976 level.

In the Arctic Islands Cominco Ltd. discovered (1971) one of the world's largest Mississippi Valley type lead-zinc deposits on their Bankeno Mines option. The Arvik deposit on Little Cornwallis Island (2 Map 1) in the Cornwallis Fold Belt contains approximately 25 million tons, averaging approximately 20% combined lead-zinc in one massive zone localized in the Thumb Mountain Formation along the early Devonian, sub-Disappointment Bay angular unconformity. Smaller deposits and spectacular showings have also been found in the area, but weak markets, a nearly complete absence of infrastructure, and the hesitancy on the part of the Canadian Government to agree on the operating parameters for the Arvik find have prevented it from coming to production. Exploration, which in 1974 covered four prospecting permits and thirty claim groups, almost completely died in this region but a production decision now made for early 1982, exploration has begun again in the area.

An even more extensive base metal rush developed in the Cordillera where Canex Placer discovered immense shale hosted stratiform sedimentary lead-zinc deposits near the east edge of the Selwyn Basin. Although the bulk of Canex's Howard's Pass deposits lie in the Yukon Territory (10 Map 1), the exploration surge generated by the discovery spread east into the Mackenzie Mountains where targets were carbonate hosted Mississippi Valley type lead-zinc in Paleozoic and late Proterozoic (Hadrynian) carbonates, and copper rich beds in Hadrynian clastics. Innumerable showings and many small rich deposits have been found but few have any hope of being producers in the present economic climate, considering the remoteness of the area and the lack of transportation systems and infrastructure.

Millions of dollars were spent mainly on drill test, of the copper potential in the upper carbonate subunit of the Helikian/Hadrynian Little Dal Group (Jefferson, in EGS 1978-5). Extensive copper deposits have been found in the Redstone Copper Belt (12 Map 1) but none appear to be economic under present or forseeable conditions.

Similar expenditures were made between 1973 and 1978 looking for lead-zinc deposits in Helikian and lower Paleozoic carbonates. None of the finds made to date are large enough to be mined and most appear to be small, structurally controlled high grade deposits probably produced by remobilization of low grade sedimentary lead and zinc. Most contain yellowish to reddish low iron sphalerite. The Gayna River discoveries (13 Map 1) of Rio Tinto Ltd. appear to have the most potential for large tonnage, but these deposits are more properly described as Mississippi Valley type. With the weakness of base metal prices, particularly zinc prices and the limited successes, activity had declined from a high in 1975-76 when at least 40 properties were extensively explored and a number of regional surveys undertaken, to a new low in 1978 when only 15 properties were worked. Increased activity in 1979-80 and 81 have resulted from expanded tungsten exploration and attempts to bring the Cadillac Ag base metal deposit to production.

A surge of exploration followed the abrupt increase in the gold price in 1973 but this was relatively minor compared to the amount of base metal exploration. Extensive work including underground development was done on O'Brien's Cullaton Lake deposit in the Churchill Province and on four properties in the Slave Province, the Camlaren, WT, Bullmoose, and Salmita. Five gold properties were drilled in 1973, eight more were drilled in 1974 and one was drilled in 1975.

Rapid inflation and fluctuations in the price of gold kept exploration at a low level from 1974, but the increase which began during 1977 with drilling on the the Crestaurum, Lynx Yellowknife and YT properties has continued to develop, spurred by higher gold prices and a devalued Canadian dollar. Cullaton Lake Gold Mines Ltd. plans to have the 'B' zone iron-formation hosted high grade gold deposit on stream by September of 1981, Giant's Salmita property should follow in a year of so as will Echo Bays much larger Lupin Mine whose production will be nearly equal to the total NWT gold production for 1980.

MINERAL EXPLORATION SUMMARY

SUMMARY

Mineral exploration in the Northwest Territories in 1980 exceeded the new high levels established in 1978 and 1979. Over 160 projects were conducted, at least 20 more than in 1978, (Table 1) and important production decisions made for the Lupin, Cadillac, Polaris (Arvik mine) and Cullaton Lake Mine's.

TABLE 3 COMPARISON OF ACTIVITY

GEO-REGION	PROPERTIES EXPLORED EACH YEAR 1975-81						
	75	76	77	78	79	80	81*
Cordilleran Prov.	25	28	13	14	21	29	7
Arctic Islands Baffin & Mellville	8	9	6	8	4	7	4
Keewatin (Churchill Prov.)	31	37	38	36	48	53	41
SE Mackenzie (Churchill Prov. Nonacho & Thelon Areas)	3	7	11	7	13	14	20
East Arm Sub-Prov.	10	7	2	7	6	4	7
Pine Point Dist.	3	4	3	7	5	6	4
Bear Prov.	18	27	35	32	32	22	12
Slave Prov.	44	44	28	29	33	29	24
TOTALS (NWT)	139	163	136	140	162	164	119

The increasing pace of exploration is partically shown in tables showing the number of drilling projects and the amount of drilling done in various areas. (Tables -2, -3, -4, -5). Projections for 1981 suggest a level of exploration similar to that of the last few years. Gradual weakening of Uranium interest may be offset by increased precious metal exploration, though the current decline in gold and silver prices may put a damper on that as well.

TABLE 4 HIGH COST PROJECTS

Conducted 1975 to 1980

In the N.W.T.

	75	76	77	78	79	80	81*
Drilling Projects	47	41	40	52	61	81	36
Mines in Development	5	3	2	2	4	6	10
Mines in Production	6	6	7	7	8	9	7

* Projection from data available June 1, 1981

Tables -1 and -2 above and -3 below compares the activity levels in recent years. A shift of effort to the Keewatin, Southeast Mackenzie areas and to the Bear province and away from the Arctic Islands and the Slave Province is apparent. This is because of the uranium potential of the Baker Lake - Dubwant - Thelon, Nonancho and Hornby Bay districts.

Figures for daimond drill footages (Table I-1) also shows the shift to uranium exploration.

Changes in exploration target causes property acquisition to shift from one area to another as some areas are far more favourable than others for specific commodoties. Table 4 shows changes between 1975 to 1979 in permit acquisition and claim staking. The 1979 concentration of permit acquisitions in the Churchill and Bear, Geological provinces indicate the abundance of rocks considered favourable for hosting uranium deposits there.

TABLE 5 COMPARISON OF CLAIMS STAKED AND PROSPECTING PERMITS ISSUED IN 1975 TO 1981

A.

GEOLOGICAL REGION	PROSPECTING PERMITS 1975	1976	1977	1978	1979	1980	1981
Arctic Islands (Non PC)	0	0	0	10	0	10	2
Cordilleran Province	3	1	0	5	1	11	9
Churchill Province	12	53	25	50	22	57	54
Bear Province	2	13	8	10	26	17	4
Slave Province	1	1	1	0	0	3	4
TOTALS	18	68	34	75	99	98	73

B. GROUND STAKED DURING 1975 to 1981
IN VARIOUS GEOLOGICAL 'PROVINCES' IN HECTARES

	1975	1976	1977	1978	1979	1980	1981*
Arctic Islands (Non PC)	10,539						
Baffin Island (Churchill Province)	439	860	1,380	82,148	16,035	9,680	
Keewatin Region (Churchill Province)	89,411	214,000	108,000	602,171	438,770	518,055	47,488
Churchill Province (West of Keewatin)	8,406	30,400	78,700	322,506	322,091	175,491	24,213
Slave Province	112,329	62,200	67,800	36,711	35,564	50.996	56,544
East Arm Subprovince	5,980	1,460	2,130	3,376	11,106	21	
Bear Province	24,047	45,000	170,000	59,667	178,113	40,062	13,216
Pine Point District (Interior Plains)	47,696	49,200	5,620	255,269	131,890		2,487
Cordilleran Province	10,643	8,200	19,900	18,918	14,309	25,243	2,780
TOTALS	309,490	411,320	453,530	1,430,796	1,147,944	899,548	146,728

* To: Mid June Only.

EXPECTED 1981 EXPLORATION

AREA	TYPE OF WORK Diamond Drilling	Reconnaissance	Ground Programs	Development	OP Mines	Total	Prospecting Permits
Baffin	0	2	1	1	1	5	0
Arctic Islands	0	2	1	1	0	4	2
Keewatin	7	2	33	1	0	4	76*
SE Mack/Pine Pt. East Arm	7	2	15	0	1	25	7
Bear/Slave	18	2	12	4	4	36	7
Nahanni	4	0	0	3	1	8	6
Total	36	10	57	10	7*	119	98

* At present (May 1981) we are aware of intensions to work on 98 prospecting permits less than half of those in good standing.

* Con includes Con, RyCon and Negus; Giant Yellowknife includes Giant, Supercrest, and Akaitcho; Terra includes Terra (Silver Bear), Norrex and Smallwood; Echo Bay includes Echo Bay, Eldorado, El Bonanza and Contact Lake.

1981 MINERAL EXPLORATION

By mid June the Geology Office had received indications that at least 114 exploration projects would take place in 1981 in the NWT.

In addition 10 deposits are in the development stage which ranges from underground exploration and shaft rehabilitation to projected production at Cullaton Lake by fall. Seven mines are producing.

In 1980 at least 127 projects were reported. With 114 in sight now there seems little indication of a decline in the number of mineral exploration projects. It is more difficult to estimate expenditures as the 36 drilling projects represent far more expenditure than the 83 non-drilling projects. Development of 10 deposits probably represents 5 times the expenditures on all other exploration.

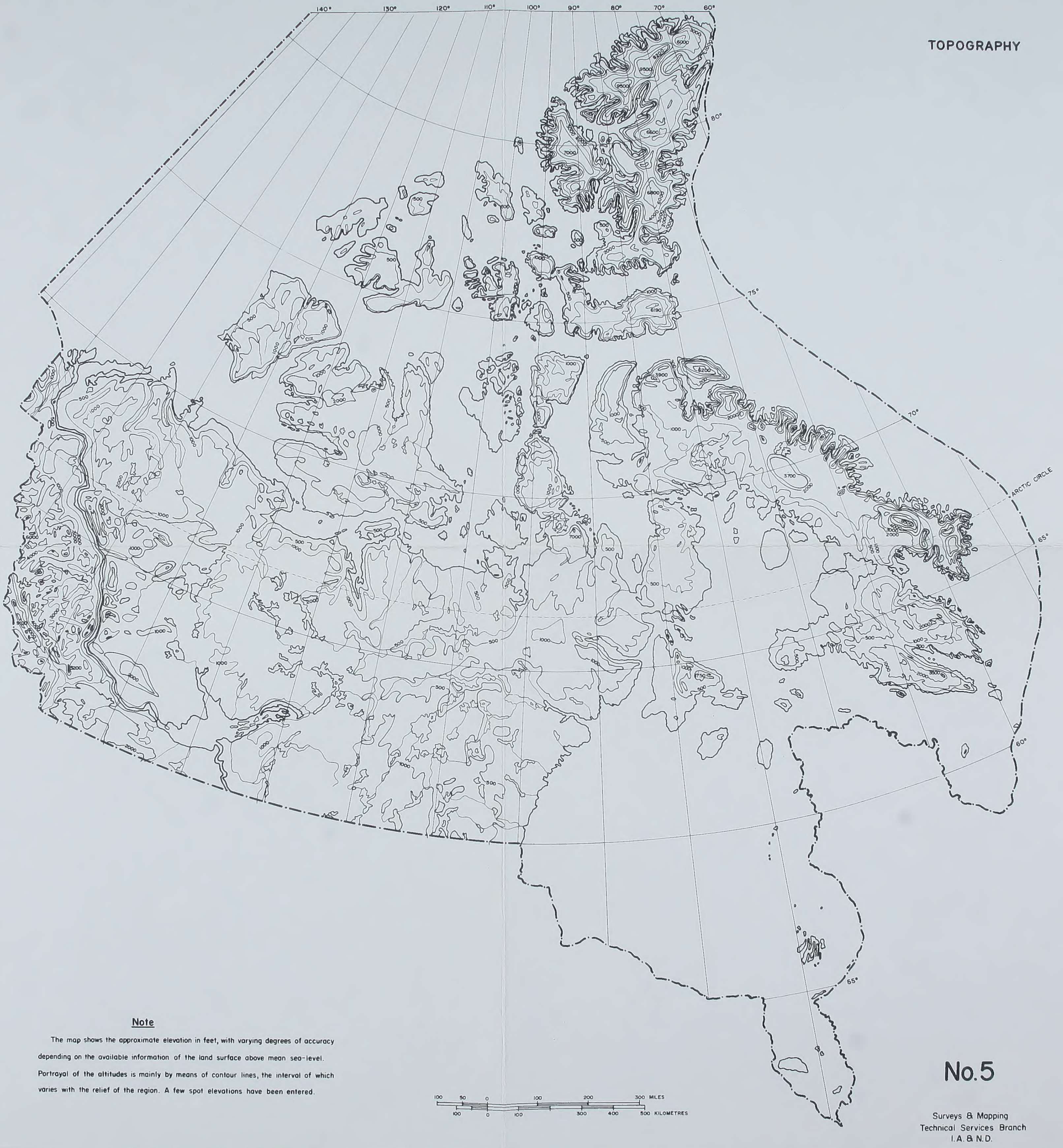
Government supported Geological work will carry on at about the same level as last year.

The Geological Survey of Canada will have 45 projects underway. Many of these involve only one man, others are much larger.

The IANA Geology Section will be assisting 4 GSC crews working out of Yellowknife with helicopter support and aggregate about 30 people. We will also assist at least 4 one or two man crews.

In addition to the 45 GSC projects IANA will have 14 or 15 field projects underway. Only one of these involves more than 3 persons.

TOPOGRAPHY



Note

The map shows the approximate elevation in feet, with varying degrees of accuracy depending on the available information of the land surface above mean sea-level. Portrayal of the altitudes is mainly by means of contour lines, the interval of which varies with the relief of the region. A few spot elevations have been entered.

No.5

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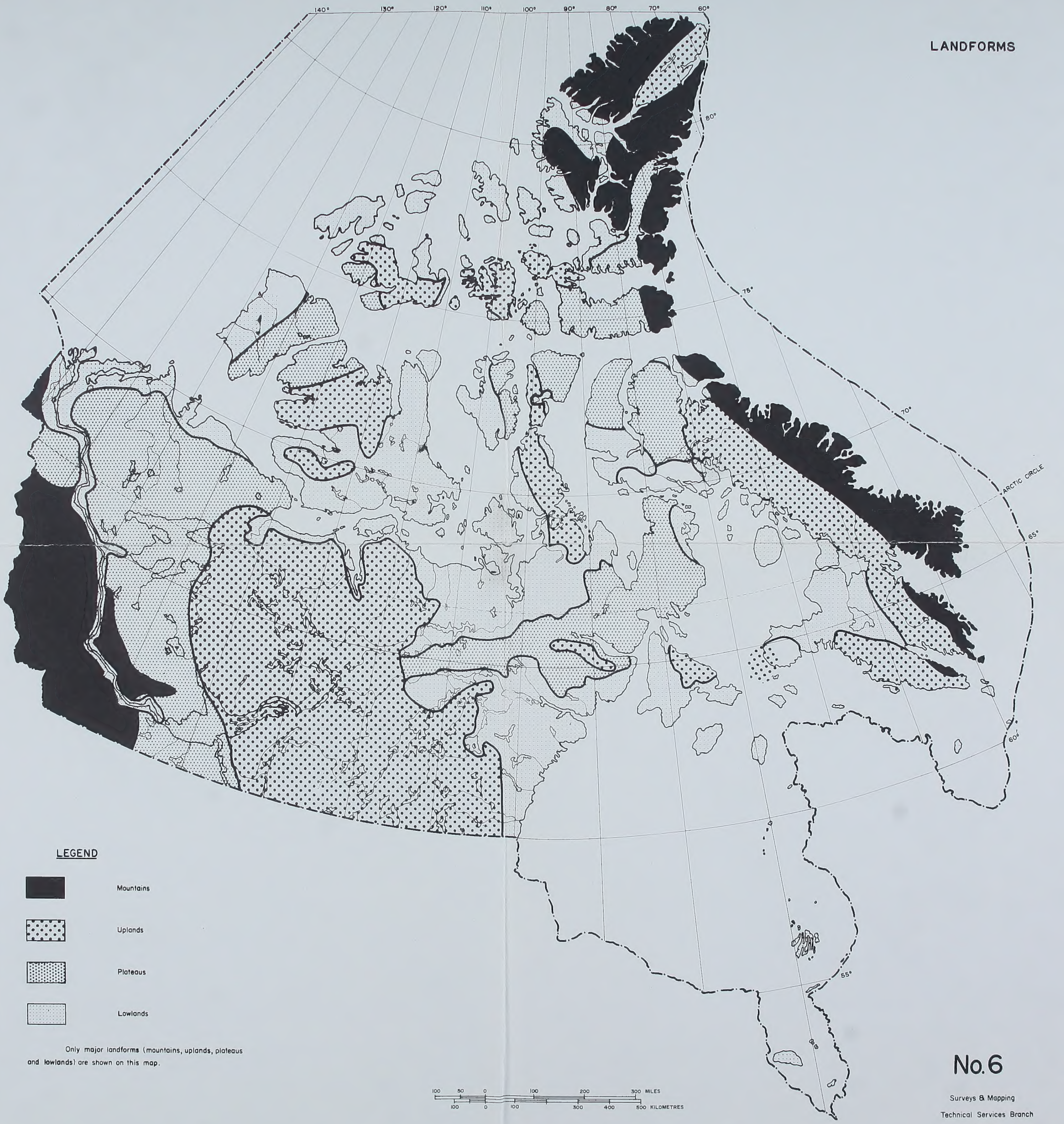
LANDFORMS



Only major landforms (mountains, uplands, plateaus and lowlands) are shown on this map.

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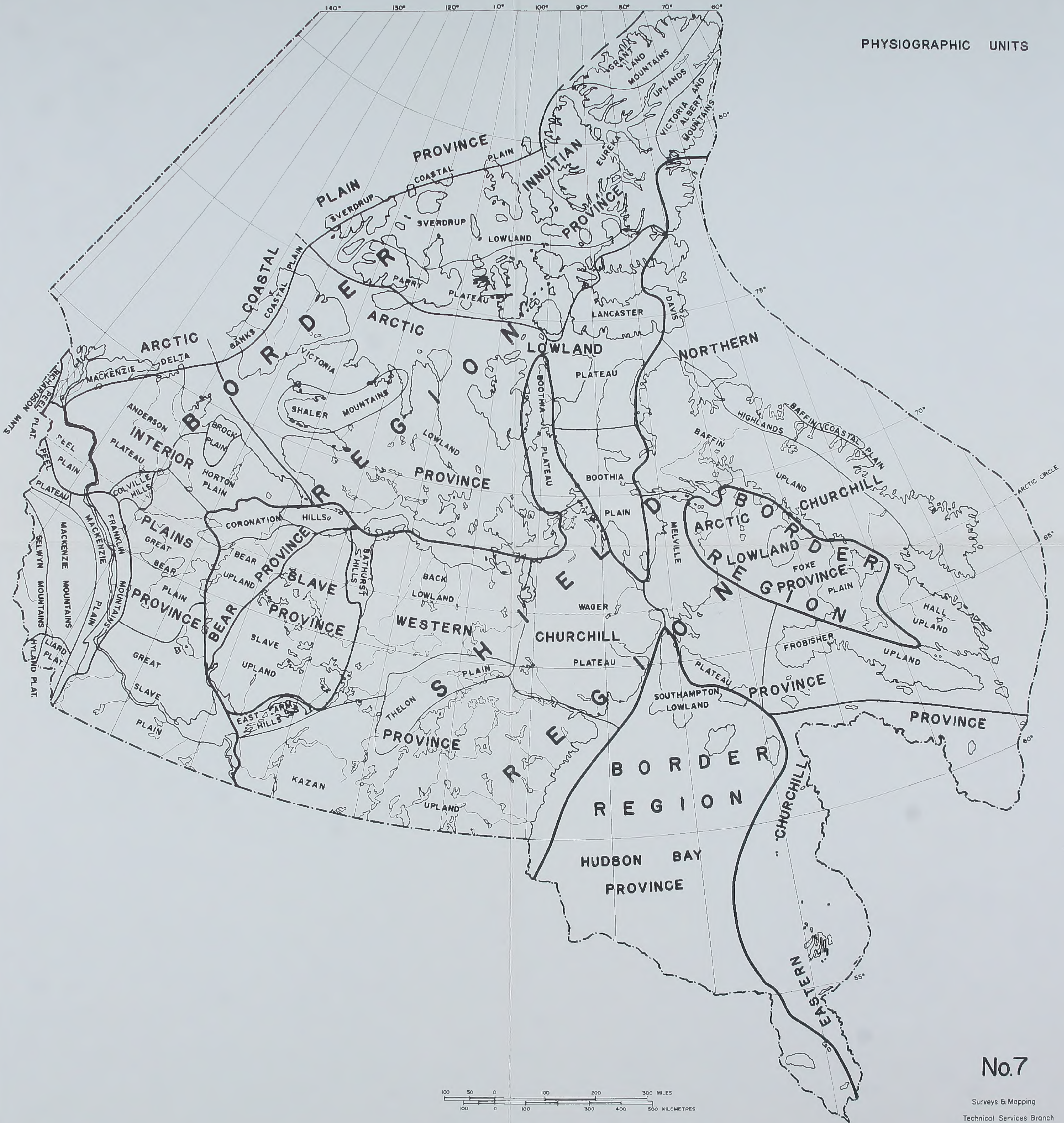
PHYSIOGRAPHIC UNITS



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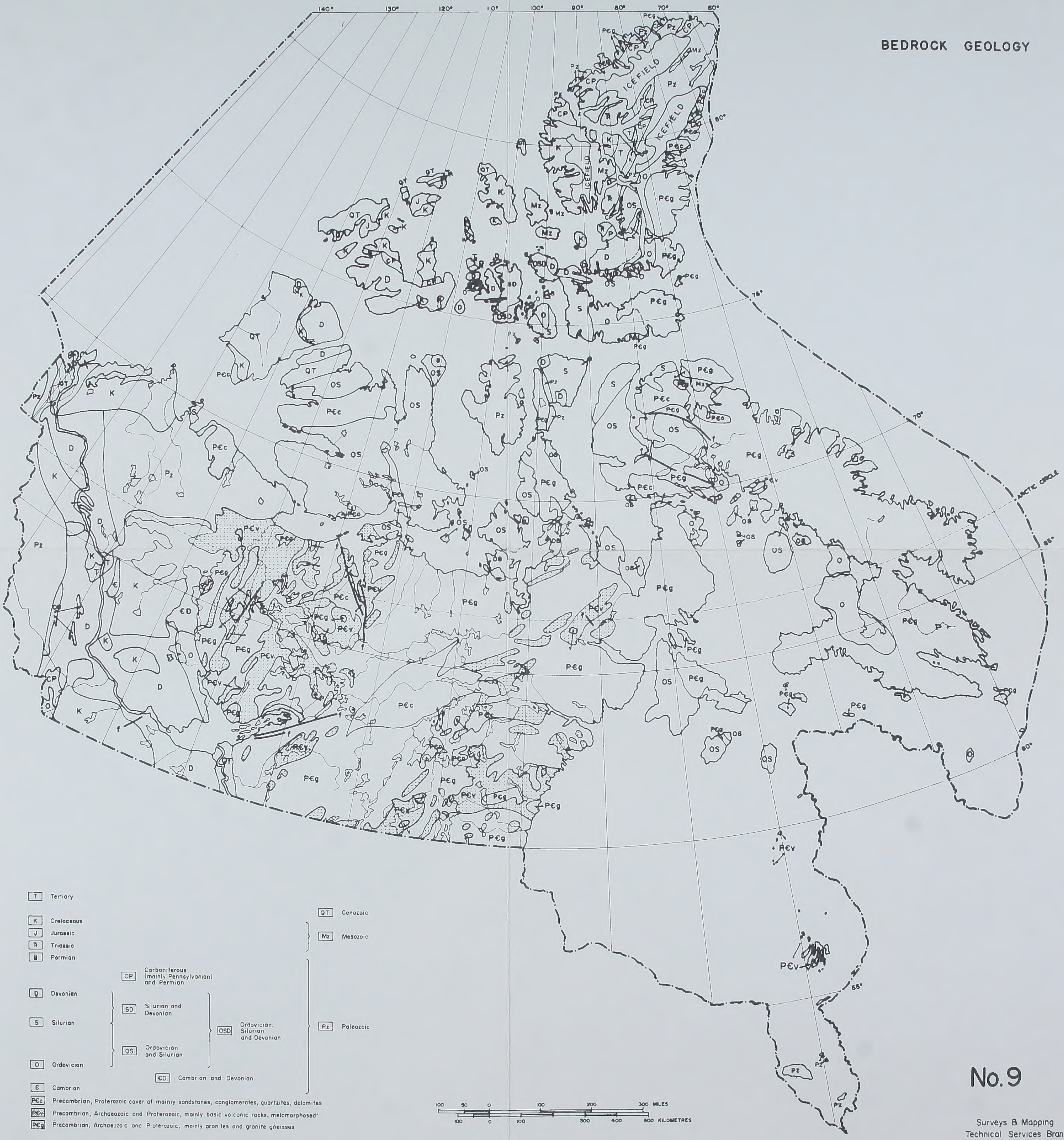
BEDROCK GEOLOGY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ARCTIC CIRCLE
ICEFIELD
ICEFIELD
ICEFIELD
T Tertiary
K Cretaceous
J Jurassic
R Triassic
P Permian
CP Carboniferous (mainly Pennsylvanian) and Permian
D Devonian
S Silurian
O Ordovician
SD Silurian and Devonian
OS Ordovician and Silurian
OSD Ordovician, Silurian and Devonian
€D Cambrian and Devonian
€ Cambrian
QT Cenozoic
Mz Mesozoic
Pz Paleozoic
P€c Precambrian, Proterozoic cover of mainly sandstones, conglomerates, quartzites, dolomites
P€v Precambrian, Archaeozoic and Proterozoic, mainly basic volcanic rocks, metamorphosed
P€g Precambrian, Archaeozoic and Proterozoic, mainly granites and granite gneisses
100 50 0 100 200 300 MILES
100 0 100 300 400 500 KILOMETRES

No. 9

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